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Efficacy of growth retardants on physiology and yield of pearl millet under rainfed condition

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ABSTRACT

A field experiment was conducted during *kharif* 2015–17 to study the efficacy of growth retardants on physiology and yield of pearl millet at Durgapura (Jaipur). Growth retardants, viz. cycocel and mepiquat chloride were sprayed @ 250, 500 and 750 ppm at tillering (40 DAS) and flowering (60 DAS) stages. The experiment was laid out in randomized block design with 4 replications. Results showed that plant height decreased, whereas chlorophyll content and relative water content increased significantly with the foliar application of mepiquat chloride @ 500 ppm over rest of the treatments. A significantly higher specific leaf weight was noted under cycocel @ 750 ppm over control. Foliar application of mepiquat chloride @ 500 ppm produced significantly higher grain yield over control. However, it was statistically at par with cycocel @ 500 ppm and mepiquat chloride @ 750 ppm. On the other hand, significantly higher fodder yield was registered with the foliar spray of cycocel @ 250 ppm over cycocel @ 500 ppm, cycocel @ 750 ppm, mepiquat chloride @ 250 ppm and 750 ppm that was at par with the control and mepiquat chloride @ 500 ppm. Maximum net returns and benefit cost ratio were accrued under mepiquat chloride @ 500 ppm. Thus, foliar application of mepiquat chloride @ 500 ppm at 40 and 60 DAS could be recommended for obtaining higher grain yield and net returns from pearl millet under rainfed condition of Rajasthan.

Keywords: Growth retardants, Morpho-physiological traits, Net returns, Pearl millet, Yield

Pearl millet [*Pennisetum glaucum* L. R. (Br.)] is an important *kharif* season crop in semi-arid and arid regions of India, sub-Saharan Africa and Southern America. India is the largest pearl millet growing country contributing 42% of total production in the world. Rajasthan, Maharashtra, Gujrat, Uttar Pradesh and Haryana are the major pearl millet producing states of India. The greater degree of adaptation of pearl millet to water stress and nutrient deprived soil are the primary reasons of its large scale cultivation in arid and semi-arid regions. The foremost challenge in these regions is the extremely low and erratic precipitation throughout the growing season that results in drought stress of different magnitude, timing, and intensity at one or other stages of crops. In India, significant progress has been made in genetic improvement of pearl millet but its impact is yet to be realized. In addition, development and up scaling of improved crop production technology of pearl millet has been a major challenge in the drought prone regions of India.

The pearl millet grows excessively under favourable conditions which lead to more diversion of photosynthates towards vegetative growth rather than reproductive growth (Shivhare and Lata 2019). Growth retardants are the chemicals which slow cell division and cell elongation of shoot tissue, and regulate plant height physiologically without formative effects leading to increased yield, improved grain quality or facilitated harvesting. Many growth retardants are known to reduce the inter-nodal length and plant height, thereby influence source sink relationship and stimulate translocation of photosynthates towards sink (Gupta and Gupta 2011, Gurrala *et al*. 2018). The growth retardants, viz. TIBA, cycocel and mepiquat chloride were found more beneficial in terms of the translocation of photo-assimilates towards developing sink compared to growth promoters under drought conditions (Kumar *et al*. 2006). Reduced plant height and increased photosynthetic processes during grain filling stage are essential for higher productivity (Gurrala *et al*. 2018). Keeping all these in views, an investigation was carried out to study the efficacy of growth retardants at tillering (40 DAS) and flowering (60 DAS) stages on physiology and yield in pearl millet under rainfed condition.

MATERIALS AND METHODS

A field experiment was conducted at Rajasthan

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Agricultural Research Institute, SKN Agriculture University, Durgapura, Jaipur during *kharif* 2015–17 situated in the semi-arid eastern plain zone of Rajasthan which lies between 27.0238ºN latitude and 74.2179ºE longitude with altitudes ranging from 431 m amsl. The climate of this region is tropical semi-arid characterized by yearly and seasonal fluctuations in the distribution of rains. During May-June, the temperature reaches 48ºC and may fall below freezing point in December-January. The average rainfall of this tract is 450 mm, of which 90% is received during June to September. The number of rainy days in the monsoon season hardly exceeds 25. The pan evaporation values vary from 0 (rainy) through 4 mm (winter) to more than 14 mm (summer). Water deficit is alleviated by irrigation wherever feasible or the plants have to face stress. The crop received 542.8, 488.2 and 457.8 mm rainfall during 2015–17, respectively in 35, 40 and 37 rainy days.

The soil of the experimental site was sandy loam in texture, having soil *p*H 8.2, electrical conductivity 0.25-0.30 dS/m, organic carbon 0.35%, available phosphorus 22–25 kg/ha and available potassium 190-200 kg/ha. The experiment, comprised of 3 levels each of growth retardants, viz. cycocel and mepiquat chloride @ 250, 500 and 750 ppm with one control (normal water). Treatments were sprayed at tillering (40 DAS) and flowering (60 DAS) stages. The experiment was laid out in randomized block design with 4 replications. The gross plot size was 5.0 m × 2 m and net plot size was 5 m × 1 m. Pearl millet hybrid RHB-173 was sown during first to second week of July during each year using seed rate of 4.0 kg/ha with spacing of 45 cm × 10 cm. The recommended doses NPK @ 60:30:20 kg NPK/ha were supplied through urea, single super phosphate and muriate of potash, respectively. Half dose of N (30 kg/ha) and full doses of P and K were applied at the time of sowing. The remaining half dose of N (30 kg/ha) was applied as top dressing at 40 DAS. The crop was raised as per the recommended package of practices.

The relative water content of the third leaf from the main ear was recorded at 70 DAS as per the method of Barrs and Weatherly (1962) and calculated as: RWC = (Fresh weight - Dry weight) / (Turgid weight - Dry weight) × 100. Chlorophyll content was also estimated at 70 DAS as per the method suggested by Hiscox and Israelstom (1979). Sample extract was prepared from 50 mg fresh leaf sample placed in 5 ml of DMSO (Dimethyl sulphoxide). These samples were heated in an incubator at 65 ^{o}C for 4 h and then cooled at room temperature. The absorbance of extracts was recorded at 663 and 645 nm on spectrophotometer. Chlorophyll content was calculated as: $Chl_{Total} = [20.2 \times A_{645} + 8.02 \times A_{663}]$. The specific leaf weight was also determined by measuring leaf area and leaf dry weight at 65 days after sowing. SLW (mg/cm^2) was computed using the formula suggested by Pearce *et al*. (1968) as: SLW = Leaf dry weight/ Leaf area.

The plant height was recorded at maturity in randomly selected three plants from each plot. Effective tillers per plant and 1000-grain weight was also recorded at harvest. The crop was harvested manually and sun-dried for 5-6 days in the field and then the total biomass yield was recorded. The grain and fodder yields were recorded after threshing, cleaning and drying of crop. The economics of different treatments was calculated by taking into account the various inputs required and outputs realized as per the prevailing cost of inputs and outputs during the respective years. Gross returns were worked out based on the prices of main produce (grain) and by-product (fodder) of the crop prevailing during each year. Net returns were estimated by deducting the total cost of cultivation from gross returns, and benefit cost ratio (returns per rupee invested) by dividing gross returns with the cost of cultivation.

All the data obtained for three consecutive years of study were subjected to pooled analysis for comparison and statistically analyzed using the F-test procedure given by Gomez and Gomez (1984). The critical difference (CD) values at $P \geq 0.05$ were used for determining the significance of differences between treatment means.

RESULTS AND DISCUSSION

Plant height decreased significantly with foliar application of both cycocel and mepiquat chloride at all the levels as compared to control except cycocel @ 250 ppm and mepiquat chloride @ 250 ppm (Table 1). The maximum decline was noted with foliar application of cycocel @ 750 ppm (170 cm) and was at par with other levels of both cycocel and mepiquat chloride. Cycocel and mepiquat chloride are anti-gibberellins dwarfing agents and, therefore, foliar spray may induce deficiency of gibberellins in the plant that reduces growth by blocking and conversion of geranyl pyrophosphate to coponyl pyrophosphate which is the first step of gibberellins bio-synthesis (Bala *et al*. 2013). A comparison of both the growth retardants showed that the mepiquat chloride was more effective to reduce plant height than cycocel. Morandi *et al.* (1984) observed logarithmic relationship between stem shortening and mepiquat chloride or cycocel in soybean but mepiquat chloride was more effective. A significant increase in chlorophyll content was recorded with the foliar application of mepiquat chloride @ 500 ppm (2.99 mg/g f.wt.) over all the treatments and it was significantly higher by 51.8, 39.1, 32.3, 37.2, 22.0 and 35.9% over control, cycocel @ 250 ppm, cycocel @ 500 ppm, cycocel @ 750 ppm, mepiquat chloride @ 250 ppm and mepiquat chloride @ 750 ppm, respectively. Kulkarni *et al*. (1995) were of the same opinion that use of growth retardants plays a positive and significant role in increasing chlorophyll content in sunflower. RWC in leaves was also recorded significantly higher with the foliar application of mepiquat chloride @ 500 ppm (77.03%) over the control and other treatments. In our previous studies, a close relationship has been observed between water relation parameters and yield in polyamines treated wheat crop (Gupta and Gupta, 2011; Gupta *et al*. 2012). It has been reported that the cultivars which maintain adequate leaf relative water content and concomitant higher root to shoot ratio can be, in general, considered as suitable for dry regions and are more tolerant

Table 1 Influence of growth retardants on growth, physiological parameters, yield and economics of pearl millet (Pooled data of 03 years)

Treatment	Plant height (cm)	Chlorophyll content (mg/g f.wt.)	Relative water content (%)	Specific leaf weight (g/cm^2)	Days to 50% flowering	Productive tillers/ plant	Test weight (g)	Harvest Index (%)	Grain yield (kg/ha)	Fodder yield (kg/ha)	Net returns (₹/ha)	B:C ratio
Control	184	1.97	69.5	169.6	49	1.3	8.94	22.1	1331	4076	14786	2.23
Cycocel@ 250 ppm	177	2.15	71.6	181.9	46	1.6	9.09	23.1	1432	4279	15900	2.29
Cycocel@ 500 ppm	172	2.26	76.0	195.7	46	2.0	9.65	23.7	1543	3996	17559	2.39
Cycocel@ 750 ppm	170	2.18	75.3	199.2	47	2.0	9.72	22.7	1437	3986	15185	2.18
Mepiquat chloride @ 250 ppm	177	2.45	72.4	177.4	48	1.7	9.10	23.5	1419	3929	15665	2.30
Mepiquat chloride @ 500 ppm	174	2.99	77.0	184.4	46	2.3	9.58	23.7	1583	4172	18412	2.52
Mepiquat chloride @ 750 ppm	175	2.20	74.0	174.6	47	1.8	9.55	22.2	1537	3896	17175	2.41
CD ($P \geq 0.05$)	8.9	0.20	4.0	19.7	1.5	NS	0.49	NS	91	256		

to drought conditions (Thivierge *et al.* 2016). The specific leaf weight that indicates leaf thickness was also recorded significantly higher with the foliar application of cycocel @ 750 ppm (199.2 g/cm^2) over other treatments including control (Table 1). Since pearl millet is a C_4 plant and an increase in leaf thickness could probably be due to enhanced photosynthetic efficiency and more stacking of mesophyll and bundle sheath cells thereby recapturing the CO_2 released during photorespiration. Grossmann (1990) reported that the application of mepiquat chloride increased the leaf thickness by 29%, having longer palisade and more spongy parenchyma cells within the leaf mesophyll and had more chlorophyll content per unit area. Curtailment of vegetative growth was also recorded with growth retardants which is evident from the data on days to 50% flowering (Table 1). Under the present study also, a significant decline in days to 50% flowering was recorded with the foliar application of growth retardants except mepiquat chloride @ 250 ppm.

There was no significant effect of growth retardants on number of productive tillers per plant but maximum numbers (2.3) were recorded with the foliar application of mepiquat chloride @ 500 ppm (Table 1). Changes in grain number due to foliar application of these growth retardants were statistically non-significant (data not reported). However, the 1000-grain weight of pearl millet increased significantly with the application of cycocel @ 500 ppm and mepiquat chloride @ 500 ppm (Table 1). The increase in 1000-grain weight with growth retardant treatments may be due to better translocation of photosynthates by reducing plant size. The foliar application of mepiquat chloride @ 500 ppm produced significantly higher grain yield (1583 kg/ha) over control, cycocel @ 250 ppm, cycocel @ 750 ppm and mepiquat chloride @ 250 ppm and was at par with foliar application of cycocel @ 500 ppm and mepiquat chloride @ 750 ppm. The increase in grain yield due to foliar application of mepiquat chloride @ 500ppm was to the tune of 18.9, 10.5, 2.6, 10.2, 11.6 and 3.0% over control, cycocel @ 250 ppm, cycocel @ 500 ppm, cycocel @ 750 ppm, mepiquat chloride @ 250 ppm and mepiquat chloride @ 750 ppm, respectively. It was also observed that with successive increase in dose of either cycocel or mepiquat chloride beyond 500 ppm, there was decline in grain yield but it could not reach to the level of significance. It is inferred that the yield enhancement could be attributed to increase in 1000 grain weight. A significantly higher fodder yield (4279 kg/ha) was registered with the foliar spray of cycocel @ 250 ppm over cycocel @ 500 ppm, cycocel @ 750 ppm, mepiquat chloride @ 250 ppm and 750 ppm and was at par with the control and mepiquat chloride @ 500 ppm (Table 1). The increase in fodder yield due to foliar application of cycocel @ 250 ppm was to the tune of 5.0, 7.1, 7.4, 8.9, 2.6 and 9.8% over control, cycocel @ 500 ppm, cycocel @ 750 ppm, mepiquat chloride @ 250 ppm, mepiquat chloride @ 500 ppm and mepiquat chloride @ 750 ppm, respectively. Application of growth retardants such as cycocel, mepiquat chloride and TIBA increased the translocation of assimilates towards developing reproductive parts and roots, thereby improved yield through the inhibition of gibberellin biosynthesis (Kumar *et al*. 2006, Patel *et al*. 2020). Harvest index did not differ significantly by foliar sprays of growth retardants.

Economic analysis of the treatments showed that maximum net returns (₹ 18412/ha) and benefit cost ratio (2.52) were accrued with the foliar spray of mepiquat chloride @ 500 ppm over rest of the treatments on pooled mean of 03 years basis over all the treatments (Table 1). On the other hand, the lowest net returns (₹ 14786/ha) were obtained under the control while benefit cost ratio (2.18) was minimum with foliar spray of cycocel @ 750 ppm.

Thus, on the basis of 03 years' experimentation, it could be concluded that foliar application of mepiquat chloride @ 500 ppm at 40 and 60 days after sowing could be recommended for obtaining higher grain yield and net returns from pearl millet under rainfed condition of semi-arid eastern plain zone of Rajasthan.

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